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The Pakihi Bogs of Westport, New Zealand

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Abstract

AN ecological survey has been made of the pakihi bogs of the Westport District. The vegetation is described by sociological analysis. Possible edaphic and biotic factors are noted and as far as possible analysed. An attempt is made to trace the botanical history.

INTRODUCTION

THE results given in this paper are from field work during the summer of 1950–51, May, 1951, and June, 1959. After eight years, little change was found in the pakihi vegetation. Some semi-pakihi areas had developed into almost true pakihi due to repeated burnings. No change was observed in true pakihi areas apart from physical changes brought about by the establishment of the New Zealand Cement Works at Cape Foulwind. The most important of these was the opening up of an inaccessible tract of pakihi stretching between Cape Foulwind and Addison's Flat. A road now connects the Cement works with their pumping station on the Okari River. (See map.)

Pakihi land on the West Coast of New Zealand is mostly wasteland. The extremely leached soil supports a low growth of fern and sedge. Due to impeded drainage the ground is exceedingly wet, often approaching semi-bog conditions.

In Holloway's (1954) report on Forests and Climates in the South Island, mention is made of the pakihis, and evidence is given for the colonisation of pakihi by forests in Westland. He makes the point that it is virgin pakihi that has been so forested. The open pakihis of today have been strongly modified by fire and thus may never follow the cycle of events as described in his report. It is this modified pakihi that has been studied in the Westport district.

A general survey was made of the pakihi vegetation in the district, thus enlarging on Townson's work of 1906. An attempt was made to discover any zones of succession existing between true pakihi and semi-pakihi areas and also between podocarp forest and the pakihi. From a study of soil, relief and climate it was hoped to establish any factors which might limit these areas.

CLIMATE AND SOILS OF WESTPORT

The most characteristic features of the climate are the relatively high rainfall and mild temperatures. Rainfall is fairly evenly distributed throughout the year but Westport, nevertheless, experiences considerable periods of bright sunshine.

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The following figures are based on a yearly average for the years 1940–1950:

Mean annual temperature	52.91° F.
Rainfall	78.2 ins.
Sunshine	2010.3 hrs.

The high rainfall, together with the mild temperatures, has resulted in excessive leaching of the soil, helping to produce the podsols of the pakihis. Pakihi soils presumably developed under a cover of Podocarpaceous forest. Either due to a climatic change or the extreme nature of the podsolisation, the forest gave way to the open sedge-fern community which predominates over most of the country. In very low-lying parts where drainage is greatly impeded, both by the iron pan of the podsol and the nature of the relief, semi-bog conditions occur. Sphagnum communities develop and peat formation is in progress.

Pakihi soils are singularly lacking in plant nutrients and are also nearly structureless due to elluviation of their clay and colloidal constituents. Consequently the vegetation they support is undemanding in its requirements.

Areas Studied (See map)

The first locality chosen was at Te Kuha. This area formed the top of one of the many "500 foot terraces" described by Bartrum (1914). Belonging to the State Forest Department, the area had not been burnt within the last 10-15 years, although it had been burnt regularly and grazed prior to this.

The second locality was chosen on the flats. A brief study was made of an area inland from Cape Foulwind and more detailed work done near Bradshaws Creek. This country is undulating, made up of gently sloping terraces, flat low-lying areas and long, fairly low ridges.

In addition, pakihis round Stockton (altitude 2,000 feet) to the North and small areas at Virgin Flat and up the Totara River to the South were surveyed.

Method of Investigation

The vegetation was analysed by means of line transects using a point analyser (Levy and Madden, 1933). The actual percentage ground covered by each species was worked out and interpreted on a graph. Braun-Blanquet's (1932) method of abundance/cover was used for small patches of vegetation of an open character which occurred infrequently along the sides of small ridges. These patches were also charted.

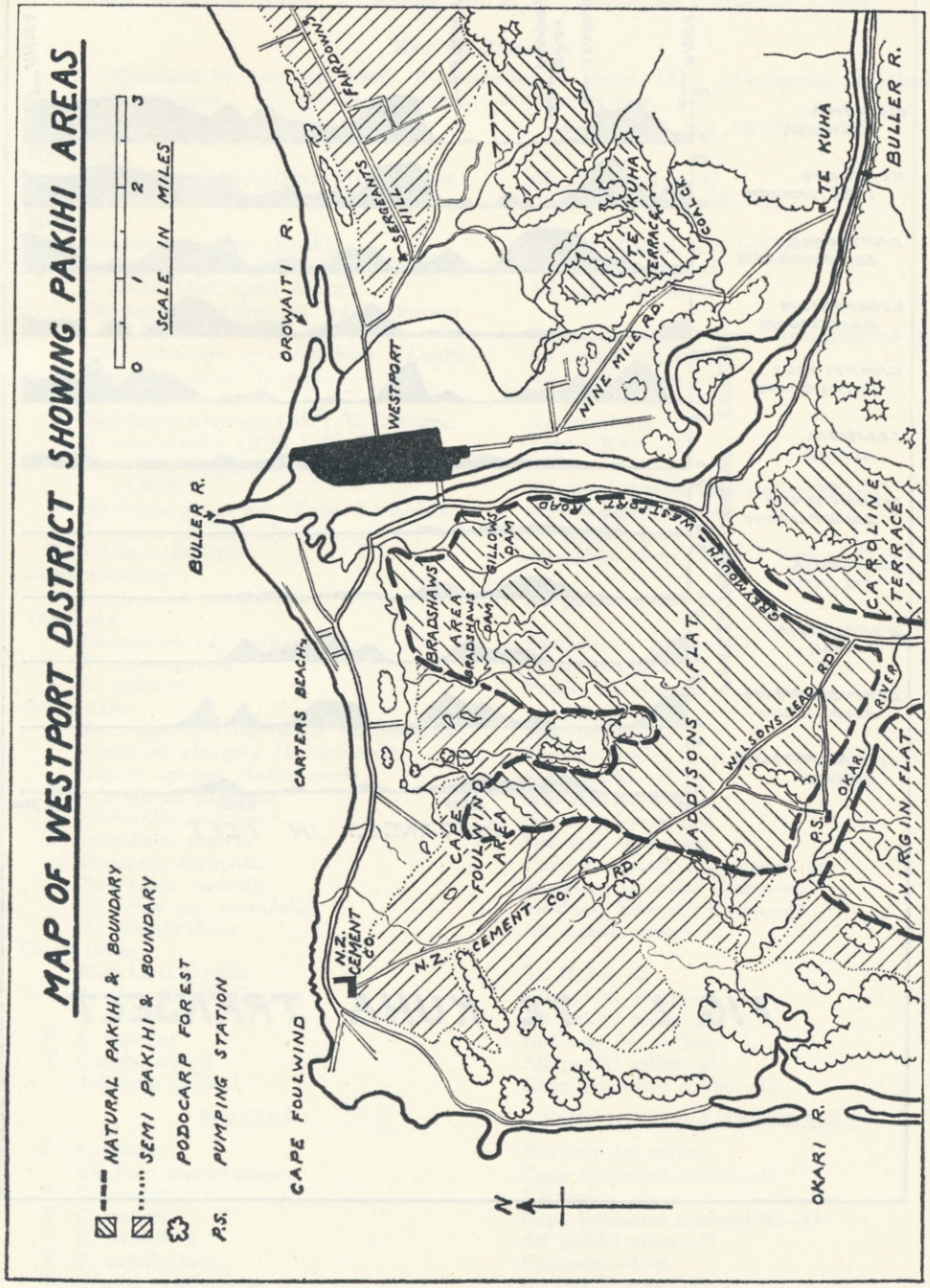
Transect lines were taken for the most part at random. However, some were chosen for their different micro-relief and some running from true pakihi through to semi-pakihi.

Soil samples were taken at intervals along one transect and from under definite patches of vegetation showing a change in dominance of species. These were later analysed.

Transects and General Survey

Pakihi vegetation can be divided into two layers. It is remarkably uniform, consisting mainly of *Gleichenia circinata* and *Cladium teretifolium* in the top layer. Both the top layer and the ground cover form mosaic patterns. Different species become dominant within small patches. *Sphagnum kirkii, Campylopus introflexus*

and *Lycopodium ramulosum* all form the mosaic in the ground cover (Plate 3, Photo 3). The pattern did not seem to be governed to any great extent by relief, nor did the different types of ground cover appear to influence the other species found with them.



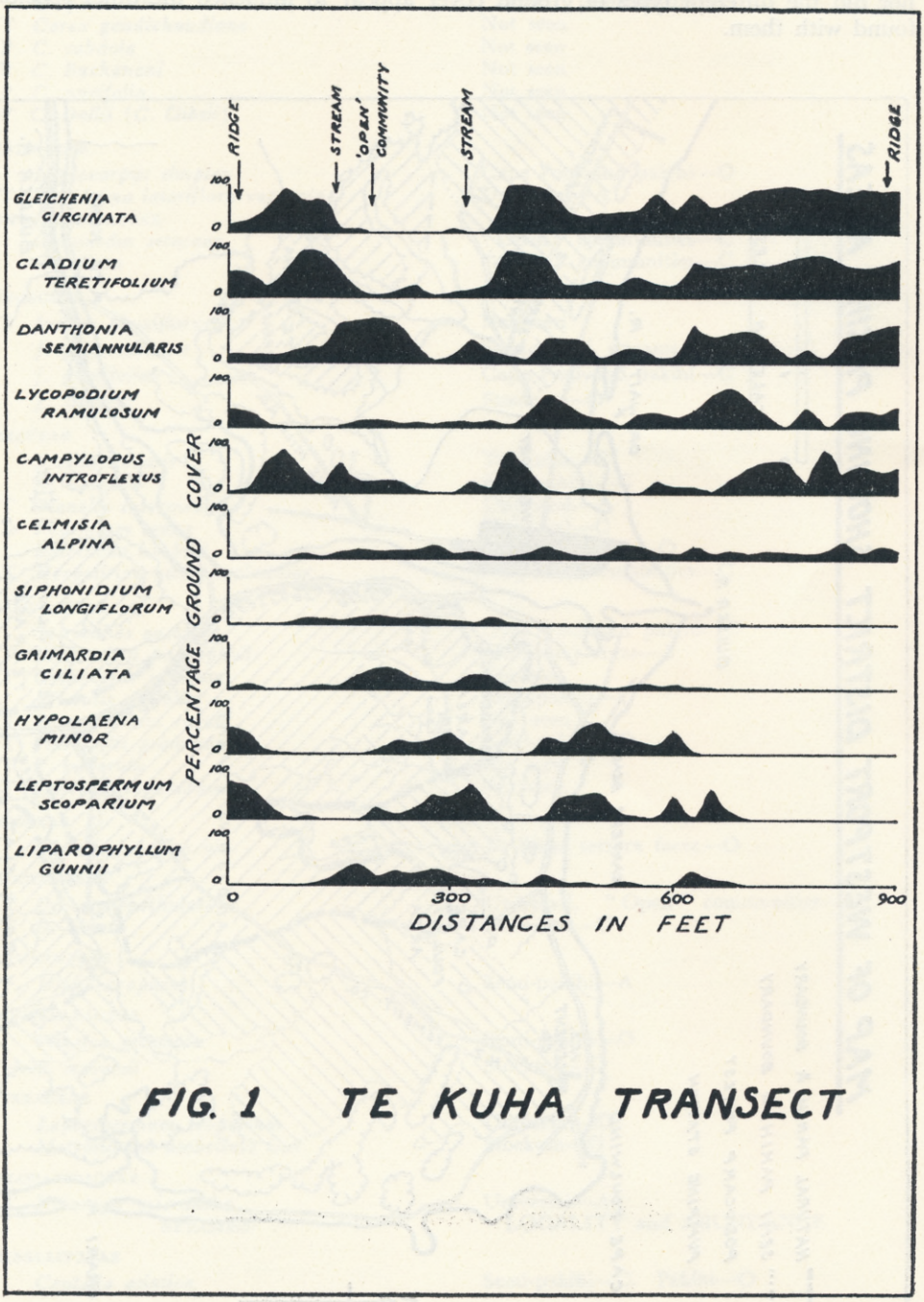


FIG. 1 TE KUHA TRANSECT

At Te Kuha the main terrace is gently rolling. Low parallel ridges, not more than six to ten feet high run the extent of the terrace in a NW-SE direction. Small drainage streams wind between the ridges ultimately draining into the gullies which dissect the edge of the terrace.

The ridges and the face of an upper terrace are much drier, due to better drainage. In places, also, granitic outcrops occur along the ridges. Consequently the species found here differ from the rest of the area. Gorse (*Ulex europaeus*) bracken (*Pteridium esculentum*) and shrubby manuka (*Leptospermum scoparium*) are common, and in a few instances odd trees of *Dacrydium intermedium* and one observed *Fuchsia excorticata* have found a footing. Such plants as *Blechnum minor, Cladium vauthiera, Epacris pauciflora* also grow successfully.

Along the sides of the ridges, generally in the folds between the spurs, distinct patches of a different type of vegetation occur. *Gleichenia* is usually absent and the plant covering is of an open nature. The patches occur quite regularly along the sides of the major ridges. Where the downslope from the ridge crest is relatively long, two lines of these " open " communities may be seen. The first runs directly below the highest part of the ridge, usually on the steepest part. The second runs at the base of the slope, the units merging on the sides of the small drainage stream. Where the slope is short the two merge together forming one oval unit. The units are quite distinct in their species combinations.

The transects taken across the area showed little variation between them, and the transect shown in Fig. 1 is typical of the area.

Starting on the downslope of one of the ridge spurs, the transect crosses a typical boggy community on the lowest lying areas, and then proceeds up a very long, gentle slope to the next ridge. From the graph it can be seen that manuka is the predominant species on the ridge, then as flat ground is attained *Gleichenia circinata, Cladium teretifolium* and *Campylopus introflexus* take over (Plate 3, Photo 1). Where the " open " bog-like community begins with extensive mats of *Liparophyllum, Gaimardia* and *Celmisia*, the *Gleichenia* completely dies out (Plate 3, Photo 2). In the top layer are now manuka, *Hypolaena* and *Danthonia*. Manuka is peculiar in that it only appears on the ridge tops and spurs or as the prostrate form in these " open " communities. It has a reciprocal distribution to the *Gleichenia* and *Cladium* which closely follow one another. As the gentle slope of the ridge is ascended the " bog-plants " *Liparophyllum, Gaimardia* and *Siphonidium* gradually disappear.

More variation in the terrain and vegetation cover was found in the Bradshaws area. North of Bradshaws Creek the land supported a Podocarp rain forest and still does in a few small pockets. From the creek the land gently slopes up to the highest part of the terrace. On the South side the terrace abruptly falls away to a flat basin-like area, very boggy with some peat formation. The southern edge of the basin area is again marked by fairly steep faces of another terrace which falls gently away still to the South. The western boundary of this area (see map) is a fairly high sandstone ridge which runs due North and South and still supports some forest. On the terraces especially on their highest parts, small ridges run in a North-South direction much the same as at Te Kuha. Again on the sides of these, and on some of the more gentle cliffed spurs on the South edge of the terrace, patches of the " open " communities make their appearance.

The terrace to the north slopes gently to Bradshaws Creek and finally drops away to the Cape Road. On its sunny slope there appears to be a greater abundance of *Danthonia* and *Cladium capillaceum*. Due to periodic burning and the consequent opening out of the vegetation, some introduced species have made their appearance. *Thelymitra pachyphylla, Microtis unifolia, Celmisia gracilenta, Blechnum minor, Taraxacum officinale* and *Pteridium esculentum* all appear to be in greater numbers on the northern side. On the flattened ridge spurs where it is very much drier,

Cladium vauthiera shows up clearly as a bright patch of orange pink. Other species which occur with *Cladium vauthiera* are *Danthonia, Haloragis, Centella, Taraxacum, Blechnum,* bracken, *Epacris* and manuka, and occasionally a small patch of *Schizaea fistulosa.*

Where the drainage streams run down the North slope, it is not so boggy as in the lower basin area. Moss communities are found on either side with a preponderance of *Siphonidium, Liparophyllum, Drosera* and *Celmisia. Gaimardia* occurs approaching the centre of some streams. The moss is mostly *Campylopus introflexus* and not peaty hummocks of *Sphagnum* as in the basin area. Once the vegetation starts to open out, there immediately seems to be an increase in the number of *Drosera.*

Towards the South, the terrace is undulating with spurs running South into the basin area. Areas in between the spurs tend to become distinctly more boggy than on the northern slopes, which have relatively good drainage into Bradshaws Creek.

In the basin area the depth of the iron pan is well over three feet, but there is poor drainage and the land is very boggy. Where there are slight drainage streams and especially along a floodwater estuary from Bradshaws dam, almost pure stands of *Gaimardia* spp. are found (Plate 3, Photo 4). Over some parts of the basin there is a considerable growth of *Sphagnum.* Growing on and through the hummocks may be *Liparophyllum, Drosera, Siphonidium, Gaimardia, Campylopus* and the odd *Gleichenia* and clumps of *Cladium teretifolium.*

Traversing the basin area are one or two earth banks thrown up for sluicing operations. Along these, introduced species such as gorse, and *Lobelia anceps,* together with manuka and bracken have found a footing.

Again several transects were taken, of which two are reproduced. Transect I, Fig. 2, descending from the 20-foot terrace and crossing the basin area shows the same relationships between the vegetation and the micro-relief as seen at Te Kuha. Where the transect cuts across a sphagnum area, the *Gleichenia, Campylopus* and *Haloragis* all show a decrease in abundance. A short transect taken through a sphagnum area in the centre of the basin shows this more clearly. (See Transect 2, fig. 2.)

In the Cape Foulwind area, there are considerable stretches of semi-pakihi as well as true pakihi. The semi-pakihi was originally forested and was probably cut over in the late 1890's (Plate 4, Photo 1). The area must have been fired many times and now appears to be reverting quickly to a true pakihi character. The micro-relief is very prominent, the country being dissected by innumerable gullies and small streams. Where there is running water in some of the deeper gullies, the banks are clothed with the remnants of the original forest—Rimus, *Dacrydiums,* lancewoods, *Coprosmas, Pittosporums* and many other species.

The margin of this " cut-over " area and the pakihi is very clearly defined. (Plate 4, Photo 1). A small drainage stream seems to run directly along the edge, dividing the slightly higher rolling country from the flatter stretches of the pakihi. The tree line stops extremely abruptly as likewise do the introduced species. Very few find their way into the uniform growth of fern, sedge and rush. In this region were found patches of the orange-stemmed *Cladium vauthiera.*

Through the " cut-over " area and across the pakihi there are myriads of blue *Thelymitras.* They seem to be far more abundant here than at either Te Kuha or Bradshaws. Patches of golden *Bulbinella* and along the stream flats a little pink *Spiranthes* add more colour.

Continuous mats of the little white starred flower of *Liparophyllum gunnii* are found everywhere on the pakihi. A little *Celmisia* is often intermingled with the *Liparophyllum* and bordering these mats are belts of *Siphonidium* with its white flowers with yellow and purple throats. The little blue *Herpolirion* and in May the handsome white *Gentiana townsoni* add to the pakihi colours.

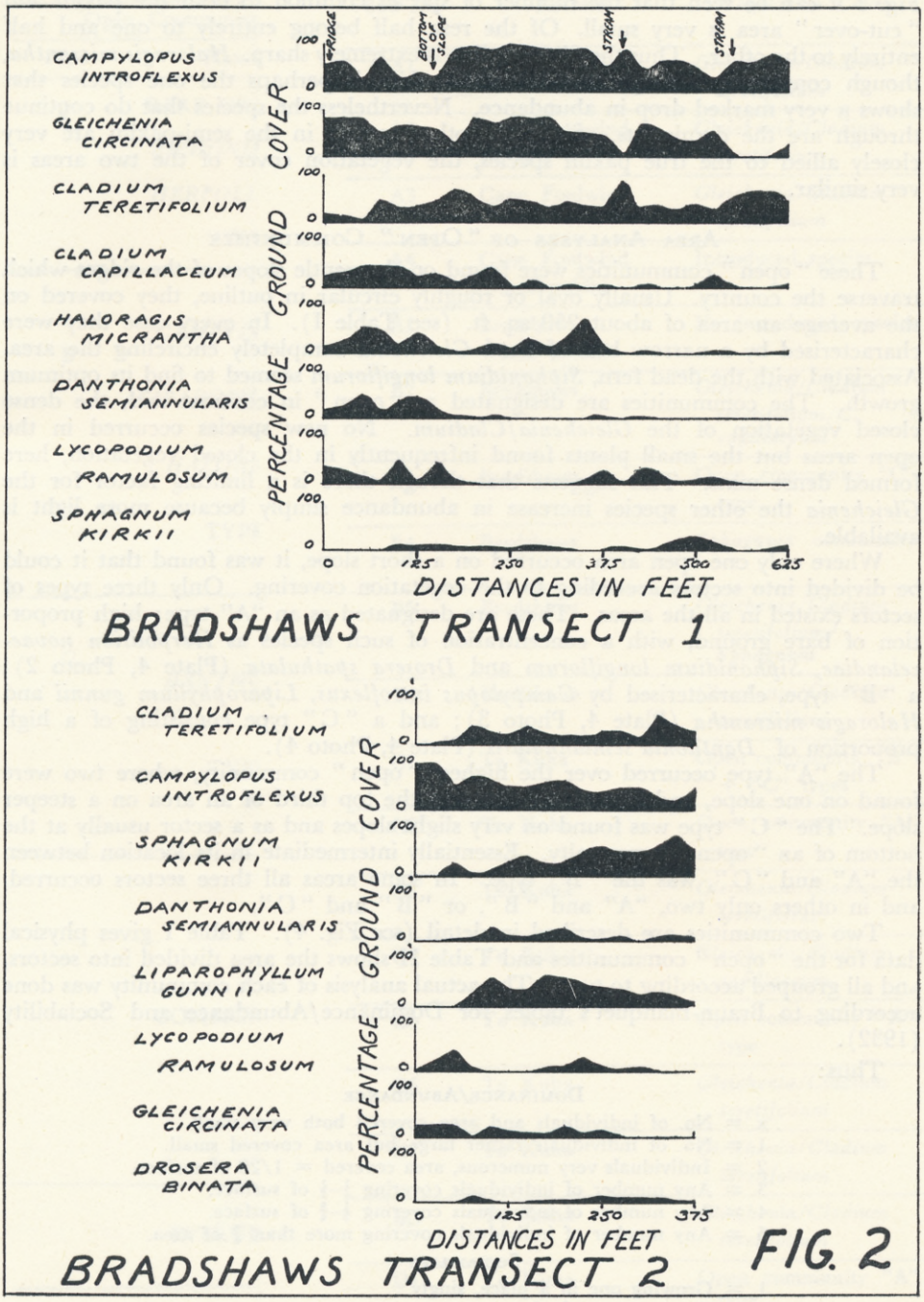

CAMPYLOPUS INTROFLEXUS
GLEICHENIA CIRCINATA
CLADIUM TERETIFOLIUM
CLADIUM CAPILLACEUM
HALORAGIS MICRANTHA
DANTHONIA SEMIANNULARIS
LYCOPODIUM RAMULOSUM
SPHAGNUM KIRKII
PERCENTAGE GROUND COVER
100
0
FRINGE
BOTTOM SLOPE
STREAM
STREAM
0
125
250
375
500
625
DISTANCES IN FEET
BRADSHAWS TRANSECT 1
CLADIUM TERETIFOLIUM
CAMPYLOPUS INTROFLEXUS
SPHAGNUM KIRKII
DANTHONIA SEMIANNULARIS
LIPAROPHYLLUM GUNNII
LYCOPODIUM RAMULOSUM
GLEICHENIA CIRCINATA
DROSERA BINATA
PERCENTAGE GROUND COVER
100
0
0
125
250
375
DISTANCES IN FEET
BRADSHAWS TRANSECT 2

FIG. 2

A transect taken in this area from the pakihi out into the semi-pakihi gave results comparable with one taken at Te Kuha from pakihi out into the bush margin. From Fig. 3 it can be seen that the number of species common to both the pakihi and "cut-over" area is very small. Of the rest, half belong entirely to one and half entirely to the other. Thus the dividing line is extremely sharp. *Haloragis micrantha,* though continuing through into the semi-pakihi is perhaps the one species that shows a very marked drop in abundance. Nevertheless the species that do continue through are the dominants. Since the other species in the semi-pakihi are very closely allied to the true pakihi species, the vegetation cover of the two areas is very similar.

AREA ANALYSES OF "OPEN" COMMUNITIES

These "open" communities were found on the gentle slopes of the ridges which traverse the country. Usually oval or roughly circular in outline, they covered on the average an area of about 250 sq. ft. (see Table I). In every case they were characterised by a narrow belt of dead *Gleichenia* completely encircling the area. Associated with the dead fern, *Siphonidium longiflorum* seemed to find its optimum growth. The communities are designated as "open" in contrast with the dense closed vegetation of the *Gleichenia/Cladium.* No new species occurred in the open areas but the small plants found infrequently in the closed vegetation, here formed dense mats. This suggests that though there is a limiting factor for the *Gleichenia* the other species increase in abundance simply because more light is available.

Where only one open area occurred on a short slope, it was found that it could be divided into sectors according to the vegetation covering. Only three types of sectors existed in all the areas. These are designated as an "A" type: high proportion of bare ground, with a concentration of such species as *Herpolirion novae-zelandiae, Siphonidium longiflorum* and *Drosera spathulata* (Plate 4, Photo 2); a "B" type, characterised by *Campylopus introflexus, Liparophyllum gunnii* and *Haloragis micrantha* (Plate 4, Photo 3); and a "C" type consisting of a high proportion of *Danthonia semiannularis* (Plate 4, Photo 4).

The "A" type occurred over the highest "open" community, where two were found on one slope, and as a sector covering the top third of an area on a steeper slope. The "C" type was found on very slight slopes and as a sector usually at the bottom of an "open" community. Essentially intermediate in its location between the "A" and "C", was the "B" type. In some areas all three sectors occurred, and in others only two, "A" and "B", or "B" and "C".

Two communities are described in detail (see Fig. 4). Table I gives physical data for the "open" communities and Table II shows the area divided into sectors, and all grouped according to type. The actual analysis of each community was done according to Braun-Blanquet's tables for Dominance/Abundance and Sociability (1932).

Thus:

DOMINANCE/ABUNDANCE

x = No. of individuals and area covered both very small.
1 = No. of individuals rather large but area covered small.
2 = Individuals very numerous, area covered = 1/20 of surface.
3 = Any number of individuals covering $\frac{1}{4}$–$\frac{1}{2}$ of surface.
4 = Any number of individuals covering $\frac{1}{2}$–$\frac{3}{4}$ of surface.
5 = Any number of individuals covering more than $\frac{3}{4}$ of area.

SOCIABILITY

1 = Growing one in a place, singly.
2 = Grouped or tufted.
3 = In troops, small patches or cushions.
4 = In small colonies, in extensive patches, or forming carpets.
5 = In great crowds (pure populations).

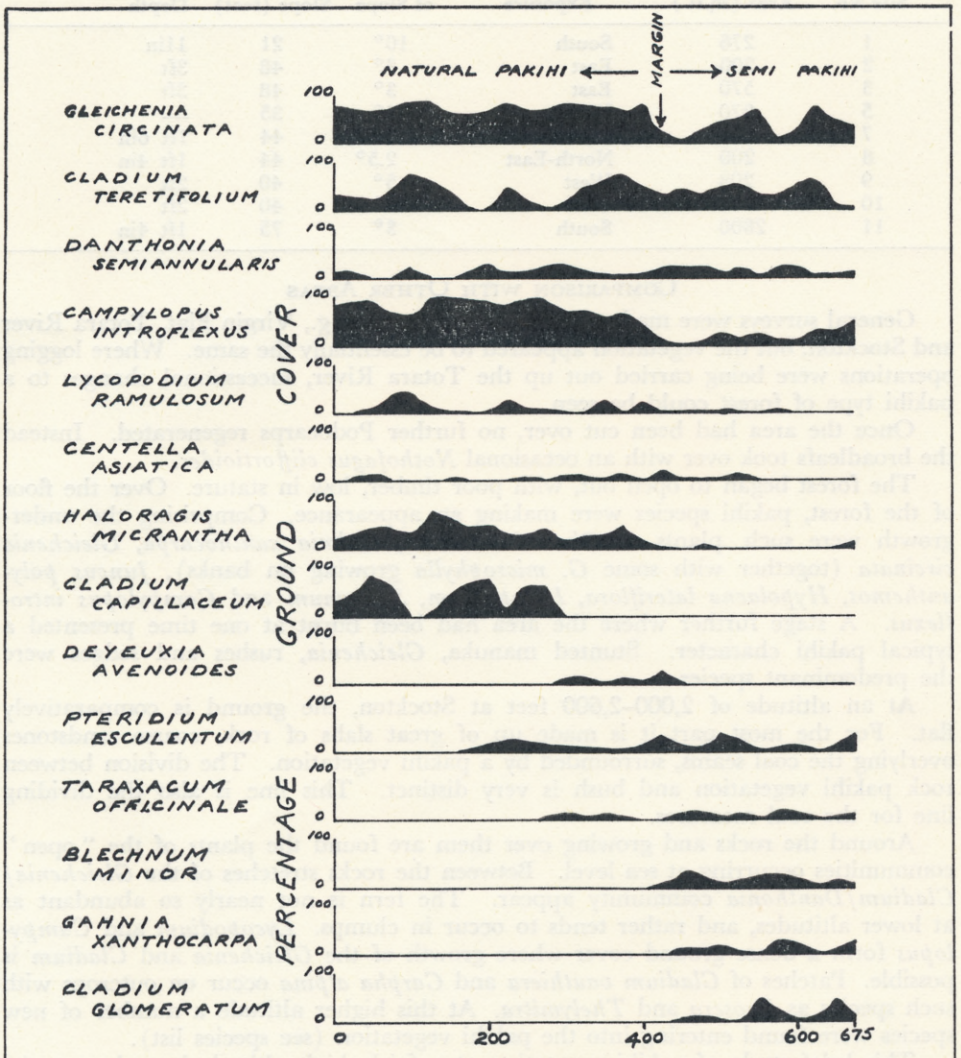


FIG. 3 CAPE FOULWIND TRANSECT

TABLE I.—PHYSICAL DATA OF "OPEN" COMMUNITIES.

Site No.	Size of Area (sq.ft.)	Exposure	Angle of Slope	Length of Slope (feet)	Pan Depth
1	276	South	10°	21	11in
2	200	East	3°	48	3ft
3	570	East	3°	48	3ft
5	270	West	3°	35	—
7	220	—	1.5°	44	1ft 6in
8	200	North-East	2.5°	44	1ft 4in
9	208	West	5°	40	2ft
10	286	West	4°	40	2ft
11	2800	South	3°	75	1ft 4in

COMPARISON WITH OTHER AREAS

General surveys were made of a few other areas—e.g., Virgin Flat, Totara River and Stockton, but the vegetation appeared to be essentially the same. Where logging operations were being carried out up the Totara River, successional changes to a pakihi type of forest could be seen.

Once the area had been cut over, no further Podocarps regenerated. Instead the broadleafs took over with an occasional *Nothofagus cliffortioides.*

The forest began to open out, with poor timber, low in stature. Over the floor of the forest, pakihi species were making an appearance. Comprising the undergrowth were such plants as *Phormium tenax, Gahnia xanthocarpa, Gleichenia circinata* (together with some *G. microphylla* growing on banks), *Juncus polyanthemos, Hypolaena lateriflora, Lycopodium, Sphagnum* and *Campylopus introflexus.* A stage further where the area had been burnt at one time presented a typical pakihi character. Stunted manuka, *Gleichenia,* rushes and sedges were the predominant species.

At an altitude of 2,000–2,600 feet at Stockton, the ground is comparatively flat. For the most part it is made up of great slabs of rock, coarse sandstones overlying the coal seams, surrounded by a pakihi vegetation. The division between rock pakihi vegetation and bush is very distinct. This line is also the dividing line for the coal measures.

Around the rocks and growing over them are found the plants of the "open" communities occurring at sea level. Between the rocks stretches of the *Gleichenia/Cladium/Danthonia* community appear. The fern is not nearly so abundant as at lower altitudes, and rather tends to occur in clumps. *Lycopodium* and *Campylopus* form a dense ground cover where growth of the *Gleichenia* and *Cladium* is possible. Patches of *Cladium vauthiera* and *Carpha alpina* occur on outcrops with such species as *Drosera* and *Thelymitra.* At this higher altitude a number of new species were found entering into the pakihi vegetation (see species list).

This brief study of pakihi vegetation at a fairly high altitude brought out the alpine character of the lesser species occurring throughout pakihis at sea level. In a number of cases the plants occurring are given an alpine or sub-alpine range by Cheeseman (1925).

EDAPHIC FACTOR

Because of the intense leaching during podsol development, pakihi soils are exceedingly low in plant nutrients, low in clay content, and very acid. Pakihi soils in the Westport district have been classified into a number of types by C. S. and A. C. Harris (1939). Transects taken on the Cape Foulwind area correspond to O'Malley sandy loam and silt loam, and the semi-pakihi on "cut-over" country to the Bulls sandy loam and sand. In the Bradshaws district, the terrace transects are in the Gillow complex series, and in the basin area on peat. The entire area at Te Kuha is of the German fine sandy loam type.

Photo 1.—*Gleichenia/Cladium* community. Photo 2—Drainage valley showing absence of *Gleichenia*. Photo 3.—Mosaic of *Sphagnum* and *Campylopus*. Photo 4—*Gaimardia* community.

Photo 1—Open pakihi beyond "cut-over" country. Photo 2—"Open" community, Type A. Photo 3—"Open" community, Type B, with *Liparophyllum* in flower. Photo 4—"Open" community, Type C, with *Danthonia*.

TABLE II.—AREA ANALYSES OF "OPEN" COMMUNITIES.

(Figures represent Braun-Blanquet's for Abundance/Dominance-Sociability.)

Open Community			Type A Site Nos.					Type B Site Nos.						Type C Site Nos.				
Type	Name	Species	1A	9A	10A	11A	8	5	1B	9B	10B	7B	11B	2	3	7C	$11C_1$	$11C_2$
A	BARE GROUND	Bare ground	3	3	—	3	3	—	—	—	—	—	1	2	2	—	—	—
		Drosera spathulata	1, 1	2, 1	2, 1	1, 1	1, 1	1, 1	x, 1	1, 1	1, 1	x, 1	1, 1	x, 1	1, 1	x, 1	x, 1	1, 1
	SIPHONIDIUM	*Siphonidium longiflorum*	3, 4	2, 3	2, 2	1, 2	2, 2	2, 4	2, 4	1, 3	1, 2	—	x, 2	—	—	—	1, 2	2, 2
	HERPOLIRION	*Herpolirion novae-zelandiae*	—	3, 2	4, 2	1, 2	—	x, 2	—	—	2, 2	—	—	—	x, 2	—	—	1, 2
	TYPE	*Donatia novae-zelandiae*	—	—	—	x, 3	—	—	—	—	—	—	—	—	—	—	—	—
B		*Haloragis micrantha*	2, 1	2, 1	3, 1	1, 2	x, 1	3, 2	4, 2	3, 1	3, 1	1, 2	—	2, 1	1, 2	3, 2	—	1, 2
	CAMPYLOPUS	*Campylopus introflexus*	x, 4	—	—	x, 3	1, 4	1, 3	3, 5	4, 4	5, 5	4, 4	x, 3	1, 4	2, 4	2, 4	1, 4	1, 3
	LIPAROPHYLLUM	*Liparophyllum gunnii*	2, 4	—	—	1, 1	1, 2	3, 3	—	2, 4	x, 3	x, 2	3, 3	1, 4	2, 2	—	2, 2	3, 2
		Gaimardia ciliata	1, 3	—	—	2, 3	1, 4	1, 4	2, 3	2, 4	1, 3	1, 4	3, 3	—	—	1, 4	3, 3	3, 2
		Drosera binata	—	x, 1	1, 2	x, 1	—	x, 1	2, 1	1, 2	1, 2	x, 1	x, 1	x, 1	—	—	x, 1	x, 1
	HALORAGIS	*Thelymitra pachyphylla*	—	—	—	x, 1	—	x, 2	x, 1	—	x, 1	x, 2	x, 1	x, 1	x, 2	—	x, 2	—
		Sphagnum kirkii	—	1, 1	—	—	—	—	3, 4	3, 4	x, 2	—	—	—	—	—	1, 3	—
	TYPE	*Schizaea fistulosa*	—	—	1, 2	—	—	x, 3	—	x, 1	x, 1	—	x, 2	—	—	—	—	—
		Epacris pauciflora	—	—	—	x, 1	—	—	x, 1	—	—	—	—	—	—	—	—	—
		Gaimardia setacea	—	—	—	—	—	x, 3	—	—	—	3, 3	—	—	—	—	—	—
C		*Danthonia semiannularis*	2, 3	2, 3	1, 2	1, 2	1, 1	—	3, 3	3, 4	2, 2	x, 2	1, 2	3, 2	3, 3	5, 3	3, 2	3, 2
	DANTHONIA	*Cladium teretifolium*	1, 2	1, 2	1, 3	1, 2	2, 2	1, 3	2, 2	2, 3	1, 3	2, 3	—	3, 2	x, 1	3, 3	—	1, 2
		Gleichenia circinata	x, 1	x, 1	—	—	1, 2	—	x, 1	—	—	1, 1	—	1, 1	1, 2	x, 1	—	1, 2
		Cladium capillaceum	1, 2	—	—	—	—	—	2, 3	—	—	—	—	—	3, 3	—	—	—
	TYPE	*Oreostylidium subulatum*	—	—	—	—	—	—	—	—	—	—	—	1, 2	—	—	—	—
		Celmisia gracilenta	—	—	—	—	—	—	—	—	—	—	—	—	x, 1	—	—	—
		Celmisia gracilenta var. *alpina*	2, 1	2, 2	x, 3	1, 1	3, 2	4, 3	4, 4	3, 4	x, 3	1, 2	2, 1	1, 1	1, 2	x, 1	2, 1	3, 2
		Leptospermum scoparium	—	x, 1	x, 1	2, 1	—	—	1, 1	3, 1	4, 1	—	3, 1	—	—	—	3, 1	3, 1
	COMMON SPP.	*Hypolaena lateriflora* var. *minor*	—	—	—	1, 2	2, 2	—	—	—	x, 1	—	2, 2	—	—	—	2, 2	2,2
		Oreobolus pectinatus	—	—	x, 3	2, 3	—	—	—	1, 3	1, 3	—	x, 2	—	—	—	—	x, 3
		Lycopodium ramulosum	x, 2	—	1, 3	—	—	1, 2	—	1, 3	x, 3	1, 3	x, 1	x, 1	x, 2	—	1, 1	1, 2
		Microtis unifolia	—	—	—	—	—	—	x, 1	—	—	—	—	x, 1	—	—	—	—
		Dicranoloma pungens	—	—	—	x, 2	1, 4	—	—	—	—	—	—	—	—	—	1, 4	—
		Pteridium esculentum	—	—	—	—	—	—	—	—	—	x, 1	—	—	—	—	—	—
	INTRUDERS	*Eragrostis* sp.	—	—	—	—	—	—	1, 2	—	—	—	—	—	—	x, 3	—	—
		Centella asiatica	—	—	—	—	—	—	1, 2	—	—	—	—	1, 2	—	—	—	—

Soil samples from under different floristic communities were taken in each region. It was hoped that after analyses had been made, factors might be discovered which would explain the changes in vegetation observed. It was unfortunate that moisture contents could not be ascertained. It was hoped that mechanical analysis would give a picture of the water retaining capacity, but these were not altogether satisfactory.

Some attempt was made to observe profile development under ridge slopes where " open " communities occurred. No definite correlation was found between different slopes.

Table III shows some of the results obtained from the soil analyses. No definite factor can be seen in the analyses which either explains the change from " closed " to " open " community or from pakihi to semi-pakihi. The failure to find any factor which would explain the " open " communities may be related to water level and the moisture content of the soil. The way in which *Gleichenia* dies off at the periphery of these communities suggests that some element not determined may play an important part.

A few results are significant. Low nitrogen is apparently associated with the appearance of *Drosera spathulata.*

e.g., *Soil*	*N %*	as compared with *Soil*	*N %*
C_2	.09	C_3	.23
A_3	.14	A_1	.23

This is more or less to be expected as *Drosera* is an insectivorous plant.

High phosphate and improved base saturation seem to be essential for the establishment of introduced species. All soil samples taken from pakihi areas yielded very low phosphate results, ranging from a trace to .0005 per cent. Similarly available potash was also low, ranging from .0011 to .0032 per cent. Two soil samples were taken from semi-pakihi areas, but only one area had many introduced species and that one had the better figures for phosphate and base saturation.

e.g., *Soil*	*Available P_2O_5 %*	*B.S. %*
A_4	.004	30.2
B_1	Trace	12.9

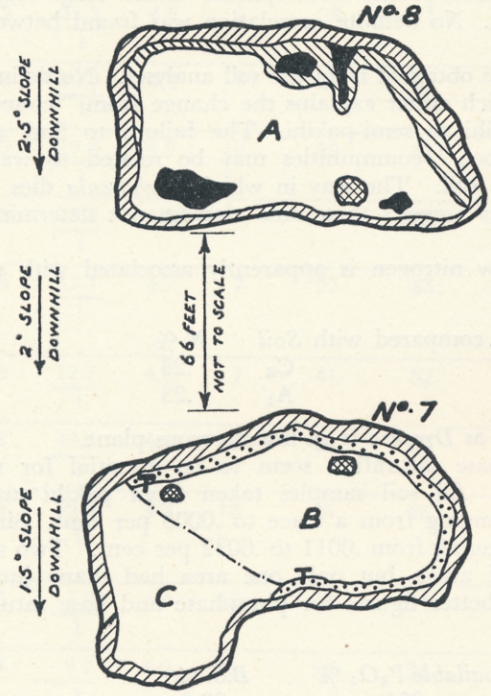
Where peat formation was going on under sphagnum communities, higher figures were obtained for carbon and total nitrogen and also for total exchangeable bases and base exchange capacity. The pH in such areas was naturally low.

e.g., *Soil*	*TEBme%*	*BEC%*	*C%*	*N%*	*pH*	
B_4	4.78	38.2	28.3	.57	4.2	*Sphagnum*
B_5	5.69	62.7	47.6	.74	4.2	
compared with						
B_2	1.33	8.87	4.4	.32	4.7	*Gleichenia/ Cladium*

The only significant fact which appears to link up the " open " communities is the degree of slope. Where the slope is very long and of the order of 4° no open communities result—e.g., B_2. Where the slope is steep, about 18°, or where there are rock outcrops, no open communities are found. But when the slope is moderate in length and from about 1° to 10° they appear.

Biotic Factors

Fire. The pakihis have been repeatedly burnt since the advent of European settlement and probably also during the time of the Maoris. Thus the pakihi has been kept in a state of abeyance for years. Even though climatic conditions may



BELT OF DEAD GLEICHENIA / CLADIUM
LYCOPODIUM RAMULOSUM
GLEICHENIA CIRCINATA
SIPHONIDIUM LONGIFLORUM
LIPAROPHYLLUM GUNNII
T THELYMITRA PACHYPHYLLA

D/A-S DOMINANCE/ABUNDANCE — SOCIABILITY

SCALE
0 FT. 6 FT. 12 FT. 18 FT. 24 FT.

TYPE A **D/A-S**

CELMISIA GRACILENTA VAR ALPINA	3, 2
SIPHONIDIUM LONGIFLORUM	2, 2
HYPOLAENA LATERIFLORA V. MINOR	2, 2
CLADIUM TERETIFOLIUM	2, 2
CAMPYLOPUS INTROFLEXUS	1, 4
GAIMARDIA SETACEA	1, 4
DICRANOLOMA PUNGENS	1, 4
LIPAROPHYLLUM GUNII	1, 2
GLEICHENIA CIRCINATA	1, 2
DANTHONIA SEMIANNULARIS	1, 1
DROSERA SPATHULATA	1, 1
HALORAGIS MICRANTHA	x, 1

TYPE B

CAMPYLOPUS INTROFLEXUS	4, 4
GAIMARDIA SETACEA	3, 3
HALORAGIS MICRANTHA	3, 2
CLADIUM TERETIFOLIUM	2, 3
SIPHONIDIUM LONGIFLORUM	2, 3
GAIMARDIA CILIATA	1, 4
LYCOPODIUM RAMULOSUM	1, 3
ERAGROSTIS SP.	1, 3
CELMISIA GRACILENTA V. ALPINA	1, 2
GLEICHENIA CIRCINATA	1, 1
DANTHONIA SEMIANNULARIS	x, 2
LIPAROPHYLLUM GUNNII	x, 2
DROSERA SPATHULATA	x, 1
DROSERA BINATA	x, 1
PTERIDIUM ESCULENTUM	x, 1

TYPE C

DANTHONIA SEMIANNULARIS	5, 3
CLADIUM TERETIFOLIUM	3, 3
CAMPYLOPUS INTROFLEXUS	2, 4
GAIMARDIA CILIATA	1, 4
HALORAGIS MICRANTHA	1, 2
CELMISIA GRACILENTA V. ALPINA	x, 1
DROSERA SPATHULATA	x, 1
GLEICHENIA CIRCINATA	x, 1

AREA ANALYSIS OF OPEN COMMUNITIES

FIG. 4

have been such that Podocarps could have established themselves on the drier ridges no seedlings would be able to survive the repeated burnings.

There is no doubt that the numbers of burnings have increased tremendously during the past hundred years. With the consequent opening out of the vegetation it is probable that a number of species have made a comparatively recent appearance in the vegetation. A comparison with Townson's list of species for the Westport pakihis in 1906 seems to suggest that this might be the case. However, it is possible he failed to record many of them. It is also possible that the open communities have increased and perhaps owe their origin to the burning of *Gleichenia* and *Cladium*. The fern is the main fire carrier and open communities frequently escape during a burn. Thus they may eventually encroach further on the closed vegetation of the *Gleichenia* and *Cladium*.

Gold Mining Operations.

In the early years of the Coast, the pakihis were disturbed to a considerable extent by the sinking of mine shafts, the digging of sluicing channels and the formation of dams. Where the pan was broken and free drainage obtained, many introduced species were able to find a footing and consequently oust the pakihi vegetation.

Pasture Improvement.

Attempts to reclaim the pakihis were made prior to and after the 1914-18 war (Easterfield *et al.* (1929), Easterfield and Rigg (1931)). None of this work proved of lasting success, and in some cases it was found that the methods used were uneconomic. However, a considerable number of farms do include areas of pakihi country. For the most part these tracts are used solely during the winter for dry cow grazing.

With an adequate top-dressing of lime and superphosphate a good pasture growth will result within a year. Farmers generally content themselves with burning the pakihi every year, enabling their cattle to eat the young *Cladium* shoots.

Deer and Wild Cattle may modify the pakihis to some extent, but it is doubtful whether they have contributed any lasting modification to the vegetation. Their only source of fodder is the tender white base of the *Cladium teretifolium* shoot, so it is possible the abundance of *Cladium* may have been affected.

CONCLUSION

Results from the study may be summarised as follows:

1. The pakihi vegetation may be divided into " closed " and " open " communities.
2. The " closed " community is composed of two major communities, *Gleichenia circinata/Cladium teretifolium* and *G. circinata/C. capillaceum,* as well as a few minor ones found in streams—i.e., rush communities.
3. " Open " communities may be divided into three types.
4. No transition zones were found between true and semi-pakihi areas.
5. Little variation in flora was found on the pakihis.
6. The pakihis and especially the " open " communities have a distinct alpine element in that a number of species normally found around 2,000 or 3,000 feet are here present at sea-level—e.g., *Carpha alpina, Gaimardia setacea, G. ciliata, Astelia linearia, Herpolirion novae-zelandiae, Gentiana townsoni, Donatia novae-zelandiae, Celmisia gracilenta* var. *alpina.*
7. Only a small difference was found between the species list and that of Townson's of 1906, suggesting there has been little change in the pakihi vegetation over the last fifty years.
8 There appears to have been an increase in pakihi conditions over the last fifty years due to logging operations and repeated burnings.
9. No conclusive factors from the soil analyses could be found which accounted for the appearance of open communities, or for the change from pakihi to

semi-pakihi.

10. Relief appears to influence the position of the "open" communities, but what intermediary factors are affected is not known.
11. The overall influencing factor appears to be the climate. The climate permitted the establishment of rain forest and through this rain forest produced the podsolised soil type.

There seems to be no doubt that the pakihi areas once carried considerable Podocarp forests. Whether the disappearance of this forest is due solely to the impoverishment of the soil by the forest itself or whether it is due to climatic changes or both, it is hard to say.

Lucy M. Cranwell (1953) thinks the rainfall was much higher previously, allowing acid peat to form on wet ground. She classifies the pakihis as a soligenous (surface flat or sloping) paludification bog (blanket bog) belonging to the oligotrophic series of sedentary types of deposit. She makes the point that these bogs are very sensitive in their water-holding capacity and plant cover, both to climatic change and to local disturbances (drainage, fire, increase of wind action). These factors tend to slow up peat formation. More wind-resistant cushion bog species have been able to adapt themselves to a wider range of conditions than can Sphagnum.

This may partly explain the spread of the mat plants in the "open" communities.

Holloway (1954), in his report gives descriptions of zones of succession from pakihi to rimu forest, throughout Westland and South Westland. However, he mentions some pakihis may be stable, resistant to colonisation by forest species, probably due to soil conditions. He points out that the North Westland forest story is a complicated one. He states that here the invasion of pakihi by forest follows no fixed pattern and the species combinations in the final stage of forest development may be endless—e.g., rimu is often followed by red beech or hard beech or both. Mountain and/or silver beech may be present, as also rata and kamahi.

He states further that degradation processes with forested lands reverting to pakihis also occur though on purely local and minor scales. On the other hand, on a major or regional scale, degradation of forest to pakihi has occurred in the past, possibly many times, for most of the larger pakihi contain buried timbers, but the process of today is the colonisation process, and this process of pakihi invasion by forest has been in full operation on a regional scale for many centuries.

That this process was not seen in the Westport district is undoubtedly due to the fact that the pakihis have been kept in their present state by repeated burnings. No forest seedlings either of Podocarp or Nothofagus have been able to establish themselves.

The reversion to pakihi as seen round Westport has a fairly well defined history. After logging operations followed by burning in the last century, the original Podocarp forest was unable to regenerate, probably due to the climatic deterioration, the soil became more water logged due to the loss of the vegetation cover, and pakihi species encroached on to these areas.

The parent material of the pakihis is of post Pliocene origin and was glaciated in Pleistocene times (Bartrum, 1914). Therefore since the Pleistocene the Podocarp forest established itself on young soils. These soils by very virtue of their occurrence within a definite climatic zone must inevitably develop into podsols.

Even granting that New Zealand has experienced climatic variations since the Pleistocene glaciations as evidenced by Raeside (1948), Cranwell and Von Post (1936) the West Coast of the South Island would still fall within the podsol group of soils, at all times since the Pleistocene.

Although it is hard to define the factors which caused the original forest to give way to the pakihi areas of today, it is suggested that a deterioration in climate

was not the main cause for the disappearance of the pakihi forests, though it may well have been a contributory one. It would seem soil conditions as influenced by the climate and vegetation, have been the deciding factor.

SPECIES LIST—WESTPORT PAKIHI AND SEMI-PAKIHI AREAS

Unless otherwise stated, all names are as in Cheeseman's Manual (1925).

KEY TO SYMBOLS

T—Recorded by Townson, 1906. P—Recorded by Petrie, 1913. A—Species abundant. C—Species common. O—Species occasional. R—Species rare.

	SPECIES	LOCALITY and ABUNDANCE
	HEPATICS	
	Acrobolbus unguiculatus (Tayl.) Mitt.	All pakihi areas—C
	Jamesoniella tasmanica (Tayl.)	Cape Foulwind pakihi—O
	MUSCI	
	Breutelia pendula (Hook)	Cape Foulwind semi-pakihi—C
	Campylopus introflexus (Hedw.) Mitt.	All pakihi areas—A
	C. kirkii Mitt. apud Beckett	All pakihi areas—C
	Dicranoloma robustum var. *pungens* H.f. et W.	All pakihi areas, "open" communities—O
	Pleurophascum grandiglobum (Lindb.)	All pakihi areas—O
	Sphagnum kirkii Warnst.	All pakihi areas—A
	FILICES	
T	*Gleichenia circinata* (SW). C. Christen.	Universal—A
	G. microphylla (R.Br.) C. Christen	Totara River—O
	Pteridium esculentum (Forst.) Diels (1899)	All areas, pakihi and semi-pakihi—C
	Blechnum procerum (Forst. f.) Labill	Semi-pakihi areas—C
	B. minor (R.Br.) Ckne.	All pakihi areas—C
T	*Schizaea fistulosa*	All pakihi areas, "open" communities—R
	LYCOPODIACEAE	
	Lycopodium ramulosum	All pakihi areas—A
	TAXACEAE	
	Dacrydium cupressinum	Semi-pakihi gullies—O
	D. intermedium	Pakihi margins—C
	D. colensoi	Pakihi margins—C
	GRAMINEAE	
	Anthoxanthum odoratum (Introduced)	Semi-pakihi—C
	Eragrostis elongata (Introduced)	Universal—C
	Holcus lanatus (Introduced)	Semi-pakihi—C
T	*Microlaena stipoides*	Not seen by author
T	*Hierochloe redolens*	Not seen by author
T	*Sporobolus indicus*	Not seen by author
	Deyeuxia avenoides	Cape Foulwind, Bradshaws—O
	Danthonia australis	Stockton, Downers Camp—C
	D. rigida var. *teretifolia*	Stockton, Downers Camp—O
	D. semiannularis	All pakihi areas—C
	CYPERACEAE	
	Eleocharis gracilis	Te Kuha—C
	Scirpus aucklandicus	All pakihi areas—C
	S. prolifer	All pakihi areas—C
P	*S. nodosus*	Not seen by author
T	*Carpha alpina*	All pakihi areas—C
	Schoenus axillaris	Cape Foulwind pakihi—C

	SPECIES	LOCALITY and ABUNDANCE
P	*S. nitens*	Not seen by author
	Cladium glomeratum	Cape Foulwind pakihi—C
T	*C. teretifolium*	Universal—A
T	*C. gunnii*	Cape Foulwind semi-pakihi—O
T	*C. vauthiera*	All pakihi areas—C
T	*C. capillaceum*	Universal—C-A
T	*Ghania xanthocarpa*	All pakihi areas—O

	Oreobolus strictus	"Open" communities—O
	O. pumilio	"Open" communities—O
	O. pectinatus	"Open" communities—O
T	*Carex gaudichaudiana*	Not seen
P	*C. subdola*	Not seen
P	*C. Buchanani*	Not seen
P	*C. uncifolia*	Not seen
P	*C. Dallii* (*C. Gibsii*)	Not seen
	RESTIACEAE	
	Leptocarpus simplex	Cape Foulwind pakihi—O
T	*Hypolaena lateriflora* var. *minor*	Universal—A
	CENTROLEPIDACEAE	
	Gaimardia setaceae	"Open" communities—C
	G. ciliata	"Open" communities—C
	JUNCACEAE	
P	*Juncus pauciflorus*	Not seen
	J. polyanthemos	Semi-pakihi, streams on pakihi—C
	J. planifolius	Cape Foulwind pakihi—C
	J. supinus	Stockton—O
	LILIACEAE	
	Astelia linearis	Te Kuha—C
	A. nervosa	Semi-pakihi—C
T	*Dianella intermedia*	Universal—A
	Phormium tenax	Universal—C
	Bulbinella hookeri	All pakihi areas—O
T	*Herpolirion novae-zealandiae*	"Open" communities—C
	ORCHIDACEAE	
	Spiranthes australis	Cape Foulwind pakihi—O
T	*Thelymitra pachyphylla*	All pakihi areas—A
T	*Orthoceras strictum*	Not seen
	Microtis unifolia	Semi-pakihi—O
T	*Prasophyllum rufum*	Not seen
T	*Pterostylis graminea*	Semi-pakihi—O
T	*P. puberula*	Not seen
T	*Calochilus paludosus*	Not seen
	FAGACEAE	
	Nothofagus truncata	Te Kuha terrace faces—O
	DROSERACEAE	
T	*Drosera spathulata*	Universal. "Open" communities—C
T	*D. binata*	Universal—C
	LEGUMINOSAE	
	Ulex europaeus	Semi-pakihi—A
	THYMELAEACEAE	
	Pimelea prostrata	Semi-pakihi—O
	P. traversii	Stockton—O
	MYRTACEAE	
	Leptospermum scoparium	Universal—C
	Metrosideros umbellata Cav.	Stockton—O
	HALORAGIDACEAE	
T	*Haloragis micrantha*	Universal—A
	SPECIES	**LOCALITY and ABUNDANCE**
	UMBELLIFERAE	
	Centella asiatica	Semi-pakihi—C. Pakihi—O
	EPACRIDACEAE	
	Pentachondra pumila	Stockton—O
	Epacris pauciflora	Universal—C
	Dracophyllum rosmarinifolium	Stockton—O

GENTIANACEAE		
T	*Gentiana townsoni*	Te Kuha, Stockton—R
	G. corymbifera	Stockton—R
P	*G. vernicosa*	Not seen
T	*Liparophyllum gunnii*	"Open" communities—C
	Centaurium umbellatum (Introduced)	Semi-pakihi—C
CONVOLVULACEAE		
	Dichondra brevifolia	Cape Foulwind—O
LENTIBULARIACEAE		
T	*Utricularia monanthos*	Not seen
SCROPHULARIACEAE		
T	*Siphonidium longiflorum*	Margins "open" communities—C
	Mimulus moschatus (Introduced)	Semi-pakihi—C
RUBIACEAE		
P	*Coprosma tenuicaulis*	Semi-pakihi—C
CAMPANULACEAE		
	Pratia angulata	Semi-pakihi—C
	Lobelia anceps (Introduced)	Semi-pakihi—C
STYLIDIACEAE		
	Donatia novae-zelandiae	"Open" communities—C
	Phyllachne colensoi	Stockton—O
	Forstera sedifolia	Stockton—O
	Oreostylidium subulatum	Bradshaw's "Open" community—R
COMPOSITAE		
	Celmisia dubia	Stockton—O
T	*C. gracilenta*	Universal—C
	C. gracilenta var. *alpina*	Universal—C
	Senecio bellidioides	Stockton—O
	Lactuca serriola (Introduced)	Stockton—O
	Hypochaeris radicata (Introduced)	Semi-pakihi—C
	Taraxacum officinale (Introduced)	Semi-pakihi—C

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